Appendix 2

Bioretention Design Examples

The following examples, from different locations in the U.S., illustrate a variety of concepts and specifications useful for developing bioretention facilities specific to local needs.

1. Bioretention Cell: Prince George's County, Maryland

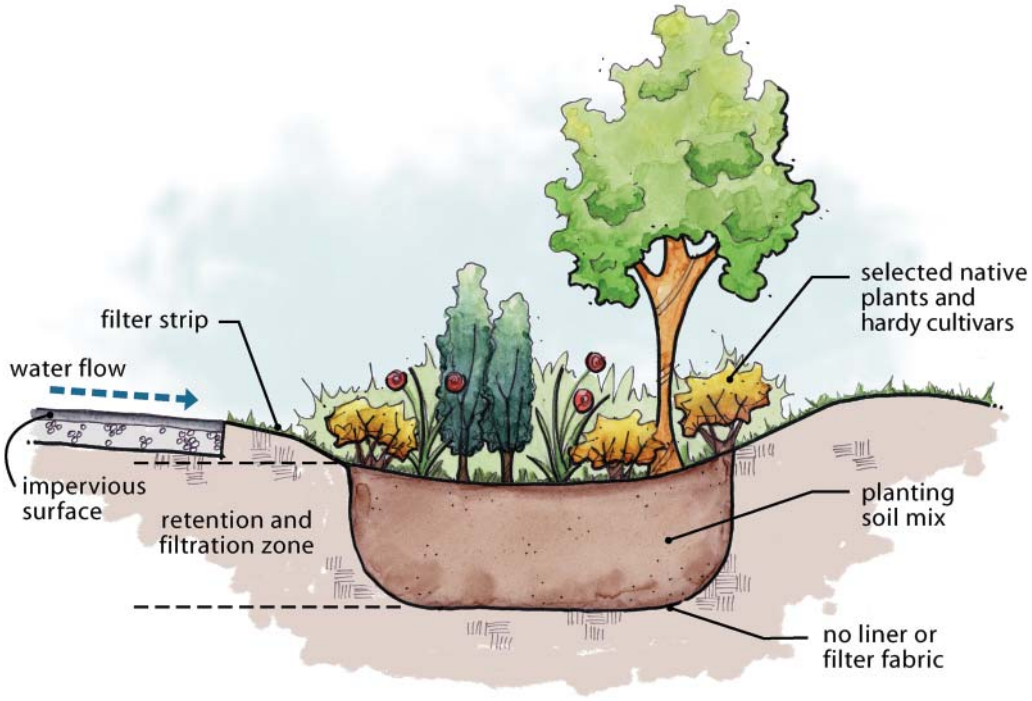

Figure 1 Typical bioretention design section.

Graphic by AHBL Engineering

Type of facility

- General application for infiltration and recharge, not recommended for contaminant hotspots.
- The initial bioretention design applied in the U.S. and the most simple design type.

Contributing area: 1-acre maximum with a maximum of ½-acre impervious area recommended.

Sizing: modified TR 55.

Flow path: off-line preferred, in-line permitted.

Planting soil depth: 2.5 feet minimum—allows for adequate filtration above native soil.

Soil:

Native soil (outside of excavated area)

- Minimum infiltration rate of 1 inch/hour.

Planting soil mix

- 50 to 60% sand, 20 to 30% leaf compost, and 20 to 30% topsoil.
- Infiltration rate not reported; however, recommended porosity for soil mix is approximately 25%.
- Topsoil is sandy loam, loamy sand or loam texture (USDA texture triangle).
- Maximum clay content < 5%.
- pH range 5.5 to 6.5.
- Uniform mix free of stones, stumps, roots or other similar material > 2 inches.
- Clean sand (0.02 to 0.04 inches) meeting AASHTO M-6 or ASTM C-33.

Comments

This is the initial planting soil specification developed for bioretention areas in the early 1990s and has been successfully applied in facilities operating for the past 10 years.

Pretreatment: provide grass or vegetated strip if space allows.

Under-drain: none

Gravel blanket: none

Filter fabric: none unless placed along sides to reduce lateral flows under adjacent pavement areas (e.g. median strip or parking lot island).

Mulch:

- 3-inch maximum, well-aged (12 months min.) shredded hardwood (shredded minimizes floating of material during surface water ponding), use fresh bark mulch when additional nitrogen retention desirable.

Compaction:

- Place soil in lifts of 12 to 18 inches.
- Do not use heavy equipment in bioretention basin.
- If compaction occurs at bottom of facility during excavation, rip to a minimum 12 inches and till 2 to 3 inches of sand into base before backfilling.
- If final grading of soil mix cannot be accomplished by hand, use light, low ground-contact pressure equipment.

Surface pool dewater: 3 to 4 hours.

System dewater: less than 48 hours.

Max ponding depth: 6 inches.

(Prince George's County, 2002)

2. Bioretention cell: Prince George's County, Maryland

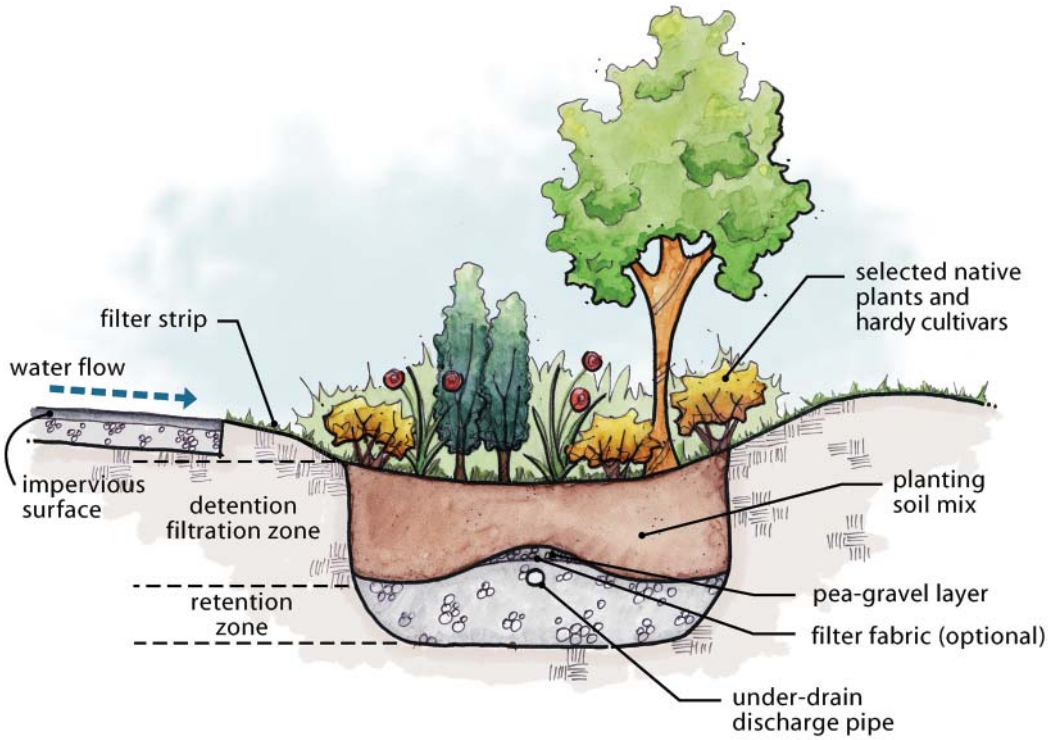

Figure 2 Bioretention design with elevated under-drain and fluctuating aerobic/anaerobic zone.
Graphic by AHBL Engineering

Type of facility:

- General application for infiltration, filtration, and recharge where high nitrogen loadings are anticipated.
- Design allows for a fluctuating aerobic/anaerobic zone below the raised under-drain discharge pipe.
- Design can be used for contaminant hotspot areas with liner.

Contributing area: 2-acre maximum with a maximum of 1-acre impervious area recommended.

Sizing: modified TR 55.

Flow path: off-line preferred, in-line permitted.

Planting soil depth: 2.5 feet minimum

Soil:

Native soil (outside of excavated area)

- Minimum infiltration rate can be less than 1 inch/hour with under-drain.

Planting soil (see Example #1)

Pretreatment: provide grass or vegetated strip if space allows.

Under-drain:

- 6 to 8-inch diameter rigid schedule 40, ½-inch perforations, 6 inches center to center.

Gravel blanket:

- Under-drain gravel bed: ½ to 1½-inch diameter washed stone AASHTO M-43.
- Pea gravel diaphragm (placed between planting soil and drain rock for improved sediment filtration): ¼ to ½-inch diameter washed stone ASTM D 448, 3 to 8 inches thick.

Filter fabric:

- Non-woven ASTM D-4491, permittivity 75 gal/min/ft^2 minimum, installed horizontally on top of the drain rock extending 1 to 2 feet either side of under-drain pipe located below.
- Filter fabric on bottom or sides of facility is not recommended unless used to restrict lateral or vertical flow.
- If pea gravel diaphragm is used, filter fabric can be placed between drain rock and diaphragm to impede direct gravitational flow.

Mulch:

- 3-inch maximum, well-aged (12 months min.) shredded hardwood (shredded minimizes floating of material during surface water ponding), use fresh bark mulch when additional nitrogen retention desirable.

Surface pool dewater: 3 to 4 hours.

System dewater: less than 48 hours.

Max ponding depth: 6 inches.

(Prince George's County, 2002)

3. Bioretention Swale: Seattle Public Utilities (SEA Street project)

Figure 3 SEA Street bioretention swale. *Photo by Colleen Owen*

Type of facility: Redesign of 660-foot existing street using bioretention swales within right-of-way for infiltration and conveyance.

Construction date: 1999 to 2000.

Contributing area: 2.3 acres (approximately 35% total impervious area).

Sizing: Santa Barbara Unit Hydrograph.

Flow path: in-line.

Planting soil depth: approximately 1 foot.

Soil:

Native soil

- Heterogeneous till-like material (not true lodgement till) with lens of silt, sand, and gravel material of varying permeability.

Planting soil

- Bottom of swales: 50% approved native soil and 50% decomposed organic compost by volume, thoroughly mixed. Remaining areas: 70 to 75% approved native soil and 25 to 30% compost by volume, thoroughly mixed.
- Infiltration rate not reported.

Comments

This soil specification has proven successful for infiltration requirements and plant growth and health at the SEA Street project; however, Seattle has modified the specification as noted in the Broadview Green Grid project (see example #4).

Pretreatment: none.

Under-drain:

- 6- to 8-inch slotted PVC pipe with surface drains set at designed flow depth elevations, solid iron pipe under driveways.
- Ultimate outfall to existing roadside ditch at end of block.
- Some areas lined with clay to restrict infiltration and possible subsurface flow to residential basements.

Gravel blanket: Seattle type 26 (sand gravel mix, see Section 6.1.2.3 Bioretention components for specification).

Filter fabric: none.

Mulch: 3-inch depth minimum (same as compost used for soil mix).

Compaction:

- No heavy equipment allowed in bioretention swale area during construction.
- No excavation during wet or saturated conditions.
- Soil installed in maximum lifts of 6 inches and foot compacted.

Surface pool dewater: not available.

System dewater: not available.

Max ponding depth: Live storage: 12 inches. Dead storage: 0 inches.

(Tackett, 2004; Seattle Public Utilities, 2000; personal communication, Tracy Tackett 2004)

4. Bioretention Swale: Seattle Public Utilities (Broadview Green Grid project)

Figure 4 Broadview green grid bioretention swale. *Photo courtesy of Seattle Public Utilities.*

Type of facility: Redesign of existing streets using bioretention swales within right-of-way for infiltration and conveyance (several blocks in length).

Construction date: 2003 to 2004.

Facility depth: 1 to 2.5 feet.

Contributing area: 2.9 to 3.7 acres (34 to 42% TIA) plus 32 acres (34% TIA) east-west streets. North-south street shown in Figure 4.

Sizing: XP-WSM

Flow path: in-line.

Soil:

Native soil (outside excavation area)

- C soils (SCS)

Planting soil mix

- Three different soil mixes are used in the Broadview Green Grid project depending on required infiltration rate, load bearing, and timing of installation.

1. Engineered Soil Mix

The Engineered Soil Mix is used in bioretention swale areas where higher infiltration rates and additional detention is desired. This mix is also used in road shoulder areas adjacent to bioretention/swales and is expected to maintain relatively good infiltration rates at 85% to 90% compaction.

- Design infiltration rate: 2 inches/hour.

Soil mix:

- 65% to 70% gravelly sand and 30% to 35% compost (see specification below).
- Gravelly sand gradation per ASTM D 422:

Sieve size	Percent Passing
2-inch	100
¾-inch	70-100
¼-inch	50-80
US No. 40	15-40
US No. 200	0-3

- The soil mixture should be uniform, free of stones, stumps, roots or other similar objects larger than 2 inches.
- On-site soil mixing or placement not allowed if soil is saturated or subject to water within 48 hours.
- Cover and store soil accordingly to prevent wetting or saturation.
- Test soil for fertility and micronutrients and, if necessary, amend mixture to create optimum conditions for plant establishment and early growth at rates recommended by an independent laboratory soil test.
- Place soil in lifts not exceeding 6 inches.

Comments

This soil specification maintains a higher infiltration rate at typical compaction rates. While the city of Seattle anticipates good performance from this specification, the mix may be slightly less optimum for plant growth than bioretention soil mixes 1 and 2 (see specification below) and has not been tested long-term for plant health performance.

2. Bioretention Soil Mix 1

Bioretention Soil Mix 1 uses on-site excavated soil mixed with compost.

Design infiltration rate: 0.3 to 1.0 inch/hour (varies with properties of native soils).

Soil mix:

- Approximately 65% approved on-site soil and 35% compost material thoroughly mixed.
- Excavated soil for mixing should be free of large woody debris or garbage (concrete or asphalt chunks, old pipe, etc.).
- Collect and test representative samples of excavated soil for gradation.
- Using on-site excavated soil is not appropriate for on-site soils with high clay content. The excavated soil should be sandy loam, loamy sand or loam texture (USDA texture triangle). The excavated soil can be amended with appropriate aggregate (e.g. sand) to achieve the appropriate texture.
- Cover and store soil accordingly to prevent wetting or saturation.
- Test soil for fertility and micronutrients and, if necessary, amend mixture to create optimum conditions for plant establishment and early growth at rates recommended by an independent laboratory soil test.
- Organic content of the soil mixture should be 8% to 12%.

Comments

On-site excavated soil, rather than imported soil, is specified as part of an overall sustainability strategy for Seattle. Using on-site excavated soil for the amended soil mix may reduce control over gradation, organic content, and final product performance, can increase project costs, and can complicate construction logistics when attempting to blend soil mix components in restricted space (personal communication, Tracy Tackett, 2004).

3. Bioretention Soil Mix 2

Bioretention Soil Mix 2 is mixed off-site and delivered ready for installation.

Design infiltration rate: 1 inch/hour.

Soil mix:

- 65% to 70% gravelly sand and 30% to 35% compost (see specification below).
- Gravelly sand gradation per ASTM D 422.

Sieve size	Percent Passing
US No. 4	100
US No. 6	88-100
US No. 8	79-97
US No. 50	11-35
US No. 200	5-15

- Maximum clay content should be less than 5%.
- Soil mixture should be uniform, free of stones, stumps, roots or other similar objects larger than 2 inches.
- On-site soil mixing or placement not allowed if soil is saturated or subjected to water within 48 hours.
- Cover and store soil accordingly to prevent wetting or saturation.
- Test soil for fertility and micronutrients and, if necessary, amend mixture to create optimum conditions for plant establishment and early growth at rates recommended by an independent laboratory soil test.
- Organic content of the soil mixture should be 8% to 12%.

Comments

The city of Seattle uses soil mix 2 during the wet season when maintaining dry native soil for mixing on-site is difficult. Bioretention soil mix 2 is a "vegetable garden mix" supplied by Cedar Grove Composting of Washington.

Compost material (for all 3 soil mixes)

- Material must be in compliance with WAC chapter 173-350 section 220 and meet Type 1, 2, 3 or 4 feedstock.
- See Section 6.2: Amending Construction Site Soils for compost specification.

Pretreatment: none.

Under-drain:

- 6 to 8-inch slotted PVC pipe, solid iron pipe under driveways.
- Under-drains connected to next downstream swale.

Gravel blanket: Seattle type 26 (sand gravel mix, see Section 6.1: Bioretention Areas for specification).

Filter fabric: none.

Mulch: 3-inch depth minimum. Compost used for mulch in bottom of swale and shredded tree trimmings in surrounding areas.

Compaction:

- No heavy equipment allowed in bioretention/swale area during construction.
- No excavation during wet or saturated conditions.
- Soil installed in maximum lifts of 6 inches and foot compacted.

Surface pool dewater: 24 hours.

System dewater: not reported.

Max ponding depth: 12 inches (total live and dead storage).

(Tackett, 2004; personal communication Tracy Tackett, 2004)

5. Sloped Bio*detention*: Austin, Texas

Figure 5 This sloped biodetention facility was a more cost-effective design for an Austin, Texas subdivision than a conventional pond. *Photo courtesy of Murphee Engineering.*

Type of facility: sloped biodetention using grassy vegetative barriers (hedgerows) on contour to detain storm flows and reduce pollutant loads.

Contributing area: not known.

Flow path: in-line.

Planting soil depth: 12-inch deep by 8-inch wide trenches excavated for planting vegetated barriers.

Soil:

Native soil

- C and D soils (SCS) on Karst formations.
- Infiltration rate not reported.

Planting soil:

- Native soil with slow release fertilizer.
- Infiltration rate not reported.

Pretreatment: rock berm used as a level spreader to distribute and release flow across slope and vegetative barriers down slope.

Under-drain: none.

Gravel blanket: not applicable.

Filter fabric: none.

Mulch: none.

Hedge plantings:

- Alamo switchgrass (*Panicum zizanioides*) in 8-inch wide rows on contour.
- Species should be adapted to local soil and climate conditions, easily established, long-lived, as well as have stiff stems that remain erect through the year. Grass species that can emerge through sediment deposits and resume growth from buried stem nodes, rhizomatous or stoloniferous growth habit are desired (Natural Resources Conservation Service, 2001).
- First row receiving discharges is double planted (one row a few inches down slope of the first row) using 4-inch slips on 4-inch centers.
- Planted at 110 stems per square foot.
- Area between hedgerows planted in grass for slope and soil stability and additional filtering.

Spacing: 25 feet between hedgerows (2 to 2.5% slope). Spacing will depend on slope.

Sizing and Hedgerow length:

- 2-year design storm (2.64 inches/3 hours) used for sizing.
- Hedgerows designed to manage 0.2 cfs discharge from contributing area per foot of hedgerow.

(Murphee, Scaief and Whelan, 1997)